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TESTIMONY OF THE FIVE PILOT PROJECTS OF THE REGIONAL INTEGRATED SCIENCES AND ASSESSMENTS (RISA) PROGRAM OF NOAA'S OFFICE OF GLOBAL PROGRAMS (OGP)

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The Importance of the RISA Program

The Regional Integrated Sciences and Assessments (RISA) Program of NOAA's Office of Global Programs (OGP) represents an important innovation in how our nation conducts science related to climate variability and society. The program, according to NOAA/OGP (NOAA Office of Global Programs, "The Regional Integrated Sciences and Assessments Program," n.d.) involves

> the intersection of three major coordinates, (1) Climate and environmental monitoring and research, (2) Economic and Human Dimensions research, especially on trends and factors influencing climate-sensitive human activities, and (3) Applications and decision support i.e. the transformation and communication of relevant research results to meet specific needs in a region. The objective of the Regional Integrated Sciences and Assessments (RISA) Program is to contribute to informing the development of place-based decision support and services in responding to climate-related risks. Enabling such services at any point in time requires a critical mass of knowledge and of capacity to apply knowledge, e.g. tailoring information to meet local needs, within each region.

Explicit in the RISA program at its core is real partnership between the scientific community and the users (decision-makers or "stakeholders") of scientific knowledge. Close stakeholder involvement is new to the climate research enterprise, but the RISA's clearly demonstrate the value of this involvement. All RISA effort is focused on climate research and communication of information required by stakeholders to support their decision-making, as well as to reduce their vulnerabilities to climate variability. The RISA's focus on regional- and local-scale science and information, and thus form the critical link between national science programs and the inherently regional ("place-based" or local) users of scientific knowledge.

Why Regional Climate Assessment and Science?

The RISA Program is a crucial link in a large chain designed to give the United States an "end-to-end" capability in climate science and its applications. The chain begins with basic climate dynamics research and the ways in which global dynamics inform understanding of how these dynamics shape or constrain patterns of climate variability over the U.S, as a whole and its sub-regions. Underlying this understanding is a substantial infrastructure related to observations in the ocean, in the atmosphere, and over the land surface and to modeling those relationships.

The RISA's complete the chain by connecting a growing capability to forecast climate on seasonal/ interannual, decadal/interdecadal, and even centennial scales. These forecasts can be applied to the concerns and activities of real people, i.e., stakeholders, in a wide range of economic sectors which are sensitive to climate variability. Demonstrably, there is significant benefit for both stakeholders and local to national economies if both can optimize the use of ever-improving climate/environmental knowledge. Viewed in this way, the RISA program produces critical learning on the difference climate makes in a world of multiple environmental, cultural, and institutional stresses. This learning can then inform planning to increase human adaptability in the face of climate variability, and resilience in the face of vulnerability. The improved generation and use of regional climate knowledge will be essential to maintaining economic growth and human health in a world of increasing environmental limitations. The five RISA projects to date have been experiments that have conclusively provided proof of concept. For this proof to be transferred to the level of routine operations, the society needs a national climate service with regional arms and legs. That is an additional link in the chain that is not developed in detail here.

Regional Climate Assessment and Science – Pilot Results

Since 1995, NOAA OGP has launched five pilot RISA's, each of which is briefly profiled below. The entire OGP RISA program presently amounts to only FY''01 - $2.4M, '02 - $3.3M. Each of the RISA's takes a somewhat different pilot approach to conducting integrated climate assessment, but each has made substantial progress in bridging the gap between national climate science and stakeholders in society. Collectively, the RISA's have also made important progress toward making the understanding of global-to-continental-scale climate useful at the regional to sub-regional scales needed by the stakeholder community. The current multi-RISA pilot arrangement provides opportunities to test different assessment approaches, assess different sectors or entities within those sectors, and build a foundation of information allowing cross-regional comparisons. The pilot RISA's have also all been successful in building strong partnerships between researchers, forecasters and stakeholders. This represents a critical breakthrough on one hand, but it also places a major imperative to raise the resources to sustain and expand the partnerships. A central theme of this imperative is that funding is needed for basic regional climate science, including observations and modeling, as well as climate assessment and climate information services.

The profile presented is based on a set of five questions:
- What do we know now that we did not know five years ago?
- What are the major climate-related policy issues facing the region over the next five years?
- How are projects designed to meet stakeholder interest?
- How is the money used and leveraged?
- What resources do we need to do the job?

On the basis of the information presented in the profile of the five RISA's, the Summary and Conclusions section will specifically answer the three questions posed by Chairman Sherwood L. Bochlert of the House Science Committee:

1. What kind of climate and weather information are needed by "consumers," such as regional resource managers, farmers, land-use planners, insurance actuaries, and emergency management agencies?

2. Do federal research programs now produce such information, and, if not, what kinds of changes in the federal research agenda are needed to develop such information?

3. How would such an expanded research agenda be coordinated with other global change research activities?

The Pacific Northwest

The CIG was established on July 1, 1995 to assess the impacts of climate variability and to project the likely impacts of climate change on four sectors
– hydrology/water resources, forests and forestry, aquatic ecosystems, and coastal zones – in the Pacific Northwest (PNW), defined to include the three states of Washington, Oregon, and Idaho. Since its inception, the CIG has made major advances in the scientific understanding of climate and its impacts in the region of concern. Therefore, to the question:–"What do we know now that we did not know five years ago?" we can say that the CIG has:

- Identified the natural patterns of climate variability in the PNW.

- Demonstrated that these patterns are dominated by two predictable, large-scale patterns of climate variation over the Pacific Ocean: The El NiÒo/Southern Oscillation (ENSO) (which varies on a time scale of 2-7 years) and the Pacific Decadal Oscillation (PDO) (which seems to vary on an interdecadal time scale. Warm phases of ENSO or PDO often bring warmer, drier weather in winter and spring, and cool phases have the opposite effect. The predictability of ENSO combined with the PDO 3 – 12 months ahead thus provides advance warning about winter and spring climate in the PNW.

- Demonstrated that PNW snowpack ad streamflow are higher in cool phases of ENSO and PDO and lower during warm phases.; extremes (droughts or floods) are much more likely to occur when ENSO and PDO are in phase.

- Simulated the projected effects of climate change on the hydrology and water resources of the Columbia River Basin, one of the largest in North America, and the source of much of the electricity generated in the PNW. Climate change would primarily result in changes in snow accumulation and melt, and a shift in streamflow timing toward increased winter runoff, earlier spring snowmelt, and reduced summer flows.

- Developed a tool for making ensemble (multiple) forecasts of Columbia River streamflow up to 12 months in advance, using predictions of ENSO and PDO phases. Initial estimates suggest that such forecasts could result in an average annual benefit of over $100 million/year for hydropower alone, while preserving or enhancing fisheries protection and flood prevention capabilities.

- Discovered the enormous impact of the PDO on the distribution and abundance of Pacific Northwest salmon from Oregon to Alaska. During warm phases of the PDO, salmon are more plentiful than usual off the coast of Alaska but less plentiful off Washington/Oregon. During cool phases of the PDO, the opposite is true.

- Suggested a connection, later verified, between episodes of increased coastal erosion and El NiÒo events. The key factors are a more southerly direction of storm-driven waves and higher than normal sea level in the northeast Pacific Ocean.

- Demonstrated a connection between the PDO and the rate of forest growth, and showed that forest fires are larger and more frequent during the warm phase of PDO.

- Suggested a connection between climate and the spread of an invasive species (Spartina spp.) which threatens shellfish culture in coastal estuaries, and a connection between ENSO and commercial shellfish growth and quality.

What are the major climate-related policy issues facing the region over the next five years?

The team's research has shown that the regional hydrology and the water resources which the physical characteristics make possible are both central to the ecological and the economic life of the region and that winter snowpack is the single best integrated signal of climate variability. However, for the Columbia and other rivers in the PNW there is little or no room for growth in supply while demands on water systems continue to grow. This level of water scarcity is relatively new and it has triggered intensifying conflict between users on both sides of the Cascade Mountains. On the East Side the principal conflict is between hydropower, irrigated agriculture, and maintaining adequate in-stream flows for fish. On the West Side the conflict is between municipal and industrial demands, hydropower, and in-stream flows for fish.

In cool-wet periods of the PDO, the intensity of the conflict can be ameliorated by the fact that larger amounts of streamflow may be available. On the other hand, in warm-dry phases of the PDO we can expect conflict to intensify because significantly less water is available. While the regional management system can cope well with floods, it is not well suited to deal with periods of drought, particularly multi-year drought, because the system is highly fragmented, no single entity is in charge, and there is little or no inter-use coordination. The region is very much at risk to a changing climate which may result in significant reductions of winter snow-pack at the same time that population growth and urbanization are increasing on the West Side.

The fish conflict represents a different dimension of the same problem. It has grown in intensity and importance because the Federal Government has applied the Endangered Species Act (ESA) to 17 ecologically sustainable units (ESU's) of salmonids in the region, giving demands for larger allocations of water a legal cast with penalties for non-compliance. This application of the ESA represents in fact a shift in the priorities for how the Columbia is to be managed as between the interests of flood control, hydropower, and fish. In real terms, the first two priorities are still dominant and the system displays considerable inertia in moving towards an accommodation for fish.

Water, fish, and trees all go together in nature, so the first two conflicts raise questions about how forests are to be managed in the region. These questions relate both to restoration and maintenance of essential fish habitat and augmenting the natural supply of water for fish. Since forested lands retain greater amounts of groundwater than unforested lands, it is possible to manage forests to augment water supply as well as trees. Once again, changing priorities imply significant shifts in strategies.

These three difficult issues have to be faced up to in the next five years, even if the climate doesn't change. But since the most serious consequence of global and regional warming is very likely to be a significant reduction in winter snowpack, the region needs to'"buy some insurance" in the form of planning to deal with both present conflicts and the probabilities of climate change.

How are projects designed to meet stakeholders' interests?

The very first act of the project was to convene a meeting, at the request of NOAA/OGP, between stakeholders in the region and climate diagnosticians within NOAA and several universities to talk about the new science of climate forecasting, a focus on impacts, and what the stakeholders wanted the program as a whole to deal with. Following this meeting, the CIG engaged in a continuous dialog with stakeholders in the four sectors of primary interest – experimenting with various formats. The subsequent research agenda has always been a blend of work the team has thought necessary combined with problems of significant concern to stakeholders. In certain cases, the work has been done on contract with the CIG. In other cases, the agencies have contributed high-level operational and managerial personnel to work with the team on designated problems.

Very close and continuous relationships have been developed between the CIG and a large number of regional stakeholders, including the Bonneville Power Administration, the regional offices of the Natural Resource Conservation Service, the Army Corps of Engineers, the U.S. Forest Service, and the U.S. Park Service. CIG is also involved with the Columbia River Intertribal Fisheries Commission and the Northwest Intertribal Fisheries Commission, the National Marine Fisheries Service, the water departments of all three states, Washington Department of Ecology, Shorelands Division (one senior member of which serves as the leader of the CIG's coastal zone sub-group), Washington Department of health (the state epidemiologist serves as the leader of the CIG's human health sub-group), Washington Department of Natural Resources, Oregon Department of Lands, Washington

Department of Fish and Wildlife, Seattle Public Utilities, Seattle City Light, the Portland Water Bureau, and many other agencies/organizations.

How is the money used and leveraged?

The money is divided among the CIG's sub-groups to work on projects of highest priority. Overall, the hydrology/ water resources sub-group constitutes the largest team effort given its importance in the region. The CIG has attempted over time to fund both a human health sub-group and an agriculture sub-group in collaboration with Washington State University but has been unsuccessful in raising the necessary funds.

The team is highly leveraged. There are only six full-time employees (two administrative) in a 25-member team, along with nine graduate research assistants and faculty from five Colleges at the University of Washington in addition to faculty at Oregon State University and the University of Idaho. Faculty are covered for only a small fraction of their time. The UW contributes substantially to the CIG's public outreach work while contracts for particular investigations have been provided by the Water Department of Seattle Public Utilities, the Portland Water Bureau, and the National Marine Fisheries Service.

What resources do we need to do the job?

In order to add the human health and agriculture sub-groups to the four sectors so far covered, and looking solely at the link in the chain represented by the RISA program, it would take \$2m/yr of 2001 dollars to support the CIG.

California Applications Program

What do we know now that we did not know five years ago?

The interest level of state officials in California in topics relating to climate change has increased markedly over the last year. Simple, clear illustrations of model results that translate atmospheric changes into regional hydrologic changes have been important "props" that have been key elements in conveying to state agencies and the public some likely impacts of climate change in the region. The estimated loss of spring snowpack has been singularly important in this regard. Also, the observed trend over recent decades toward earlier Sierra runoff and the diminishing percentage in late spring, whether caused by global human activity or not, have at the very least given to water managers a tangible face to what is often considered a hypothetical possibility. Several sectors have expressed interest from the State Resources Agency (water, forests, wildlife), Environmental Protection (water and air quality), Energy Commission as well as legislators who are interested in impacts in their own districts. Since we are a coastal state, the potential for accelerated sea level rise is an important issue. Having a credible climate simulation model(s) at our disposal 1) to make such estimates, and perhaps as important, 2) present the results using formats and techniques more readily understood by practitioners, has been invaluable in supplying information.

Concerning seasonal forecasts, stakeholders "care" about forecasts quite intensely in some years when it is perceived that climate anomalies would produce a large effect (e.g., after two years of drought). However, in other years when conditions are thought to be more "normal", there is not as much interest.

We found that temperature indicators other than thermometer readings are quite effective in translating the meaning of climate change to the public or to decision-makers. Phenological stages (e.g., first bloom of lilacs) and spring snowmelt runoff timing have furnished important, entirely independent and mutually corroborative evidence that spring has been arriving earlier across the West for the past three decades.

In some sectors like water resource management, in order to convince operational institutions that there is value to be gained from only modestly skillful climate forecasts, it is crucial to work closely with these agencies over an extended period. It may be necessary to run their operational models side-by-side with alternative new models to demonstrate utility. It is not enough to simply provide forecasts of precipitation or streamflow; the user needs to be involved and engaged interactively throughout the various steps from climate model output to his particular application/decision.

The process of assessing and integrating climate services and forecasts into local resource management procedures and agencies requires much luck and patience. Agencies, especially local agencies, are buffeted by many stresses each year and often place climate issues low among their priorities. When climate rises towards the top of their priorities, however, they are eager for help, advice, and hard facts; during these periods, much progress can be made in establishing connections and in developing long-term users of climate services. The timetable for such advances, however, is most often set by the user, and not the purveyor, of climate services.

We have a much-improved understanding of wildland fire management decision-making and a much-improved understanding of wildland fire management information needs. Climate information, though used in some strategic planning, is still not fully utilized in wildland fire management practices; especially time scales of decadal change and longer. Climate forecasts are utilized in some management applications, however, forecast skill causes many managers to be skeptical of prediction usefulness. We are convinced, though, that there is a range of forecast products beyond the short range time scales that can be of benefit to fire management. For example, statistical seasonal fire forecasts can be made with modest skill using prior years' moisture indices. The fire community has been somewhat skeptical of the value of this tool but is beginning to pay more attention. The Climate-Fire Workshops held by the University of Arizona RISA have been instrumental in promoting dialogue with the fire community. Allied with this issue, it is clear that a better organized central fire data facility would be invaluable to understand and predict climate links to anomalous fire activity across the West.

Much of our seasonal forecast attention has been placed on winter season issues (precipitation, temperature), and we have often confined our attention to regions at the scale of large watersheds (Sacramento/San Joaquin). But, climate anomalies are not confined to one season, and the footprint of climate anomalies is often super-regional in scale. For example, California draws water and power from the Colorado River system as well as from Northern California watersheds. Also, summer climate anomalies impact summer electrical air conditioning demand, and their cross-regional interconnections have not received much attention. CAP, UW, and NOAA Climate Diagnostics Center have begun to discuss this issue and how this should be dealt with in a whole-West perspective.

California has begun the largest restoration program in the world, CALFED. This $30 billion 30-year effort is an attempt to involve a broad range of stakeholders in a comprehensive plan to restore the Sacramento/San Joaquin delta and San Francisco Bay and improve water quality and ecosystem function. Climatic processes are the most important external drivers of these hydrologic systems, and climatic variability can be expected to cause myriad consequences. CAP has been quite influential in raising the climate connection to a significant level of visibility within the CALFED program. We have used a unique biological indicator of winter precipitation, blue oaks, to discover that wet and dry episodes of 6 to 8-year and approximately 15-year duration are a significant feature in the Central Valley climate of the past 400 years. These heretofore largely unrecognized shorter periods are familiar to those who have recently lived through the late 1980s/early 1990s drought, and the subsequent very wet six years of the mid-1990s. CAP and collaborators have been commissioned by CALFED to summarize the role of climate variability and change in CALFED issues and to propose areas that need dealing with by CALFED science activities. We have also provided input to the current update of the California Water Plan to guide and coordinate beneficial use of California's water resources. Gaining the notice and trust of key individuals has enormous importance in our ability to inject scientific information into institutional decision making processes.

Climate data archives are struggling to keep up with volumes of data that are collected by an assortment of observational networks. There is a new generation of remote sensing and numerical model data that needs to be properly archived and made accessible. On the other hand, crucial parts of the western climate (broadly interpreted from atmosphere, ocean, hydrology and ecology) are very poorly monitored. For example, we know that spring snowmelt runoff is occurring earlier in recent decades but don't have the fundamental information to elucidate how this is occurring in mountain snow zone. Often there is little support for these measuring and monitoring activities even though these are resources that are critical for making decisions of ours and of future generations.

During a series of visits to the major California agencies affected by climate, it became clear that the state, with the 7th largest economy in the world, has poor access to its own climatic history, and in particular to carefully de-biased diagnostic measures of recent climatic trends in temperature and precipitation, and how these vary on a seasonal basis and geographic basis within this extremely diverse state. We have taken preliminary first steps to develop a suite of such indicators in a new effort coordinated by the California Environmental Protection Agency. Also, together with Henry Diaz (DCD and Western Water Program in Boulder) and others, we have crafted a plan to organize a high elevation monitoring and research effort across the West (named "CIRCMONT") and have arranged for the inaugural meeting of key investigators and agency officials this fall.

In California, we have also used seed funds from CAP funds to build up a high elevation climate monitoring network for the Sierra Nevada, along its 400-mile length, and several cross-range transects at different latitudes. Such information is crucial to the state for present and future decision making.

Regional numerical models are still in a state of development, but are beginning to provide information at the regional and local scales. Work is needed to produce simulations and interpolations at the local and regional scale fidelity necessary for managers and policy makers.

Global model runs for both long (seasonal-decadal) and short (1-4 week) forecasts are needed to investigate predictability and process-related questions relating to climate impacts. CAP is working with J. Whittaker at CDC to run and assemble a historical medium range forecast dataset and has achieved approximately 10 years of 10+ member ensemble forecasts for 1-15d time leads, but this requires a lot of computer resources, considerable data management and progress is incremental.

ENSO has become accepted as a major driver of Western weather and climate patterns. However, the "flavors" of different ENSO events and the uncertainty associated with ENSO forecasts are still not well understood and need to be clarified. We have spent (and will continue to spend) considerable time in explaining this to media, the general public and agencies.

Human Health data are available for analysis in terms of its climate effects, but in many cases are short duration, parochial, embargoed because of confidentiality issues, and difficult to acquire. It is almost essential to work with experts in the medical or epidemiological area to provide meaningful advice and collaboration in this area.

What are the major policy issues facing California over the next five years?

1. The State Water Plan (“Bulletin 160) Update will be completed in the next few years. For the first time, it has acknowledged that climate change poses issues that should be taken into account, but it is not yet clear how seriously this will be addressed.

2. CALFED needs climate advice to inform the State/Federal Government on San Francisco Bay/Delta. In designing environmental and water use policy over the 30 years (and beyond), CALFED will be a major force in developing approaches to solving water problems within the state over the next decade or two. There are very significant needs to understand variations in climate and its extreme manifestations. As an adaptive management program, CALFED also affords major opportunities for learning how climate information is incorporated into decision-making.

3. There is a great opportunity to increase the role of science in implementing fire management plans and programs, such as a) Implementation of the national wildland fire policy; b) Implementation of increased fuels treatments; c) Implementation of rehabilitation and restoration programs; d) achieving ecosystem sustainability.

4. California will be gradually weaned from its over-withdrawal from the Colorado River, in-stream and ESA issues will continue to dominate, groundwater pumping will continue, and population growth is expected to increase at an even faster rate, especially in the San Joaquin Valley. Competition for water will continue to escalate the entire time. People will continue to flee to the forested slopes, and fire issues will remain prominent, as well as to the arid desert communities and to the lush north coast. Energy concerns will remain a long-term issue. Inter-regional connections through water and power will remain a significant force. Agriculture will continue to be pressed to reduce its water consumption. Reservoir construction is not likely to occur to any significant degree. Concern about air quality is likely to increase as new findings about its ill effects emerge. If warming continues, new diseases and pathogens will put in appearances from the south.

5. With a doubling of California’s already burgeoning population being projected over the next 30 years, each of the environmental stresses facing the State can only be expected to increase. Thus, in addition to the immediate policy issues listed above, California will probably have to revisit issues such as air quality changes, habitat preservation, human disease, and the security of its ground-water resources—all in the face of changing and variable climates. Issues that seem comfortably under control with present policies are like to flare into prominence as the environmental setting and human pressure on the environment changes in the next 30 years. Which of these will flare up in the shorter, 5-year time frame remains to be seen.

How are projects designed to meet stakeholder interests?

In deciding on thrust areas, we made value judgements based on interactions over several years with California interest groups, and our ability to provide useful information.

a) Water resources is an obvious one - huge issues face the state in this Mediterranean climate in order to serve domestic, commercial, and agricultural uses;

b) Wildfire has not been looked at carefully from a seasonal forecast perspective. There is great interannual-decadal variability and there are massive expenses and impacts;

c) Human health is relatively unscathed from a climate perspective and there are potentially large benefits from better climate information;

d) Besides seasonal-decadal impacts, all three of these are likely to be strongly affected by climate changes.

How is the money used and leveraged?

Concerning what stakeholders we work with, we require that:

- the work will lead to widespread benefit
- the partner will provide meaningful interaction so that we learn how to better apply information and how it can/will be used

The great majority is used for researcher and staff support salaries. We used a small amount last year to seed a new observational network to establish hydro/met sensor transects across the South Sierra Nevada which is representative of vital mountain watersheds that are vulnerable to climate change, and not well monitored.

We are leveraged to the hilt! Only fractional salary is available for PI's and staff and we are using other contracts to fill these in and provide for other collaborators such as graduate students and postdoctoral researchers. $500K per year doesn't go very far!

What resources do we need to address these issues?

More funding is needed. CAP is funded at $500k/yr (round number). We could easily use 4X that. Parts of these problems are getting worked on, but many aspects are not. Energy, coastal, agricultural and recreational sectors have not been addressed, and we are just scratching the surface in beginning to work with human health. We do not have the funding necessary to achieve the one-on-one and end-to-end collaboration that is required to develop better information, models and transfer technology. We have begun an observational program on a shoestring budget, and are convinced that much more can be achieved, but it will require a few $100k per year to do this meaningfully.

Linked to the point above, some key partners are needed. A few specific areas include human health and social science (economics, policy). Some natural cross-RISA links can help to satisfy this; e.g. CAP has discussed prospects of teaming with University of Arizona social scientists in studying how California water resource managers utilize climate information. Other areas like coastal ocean, forestry, urban weather/climate, transportation and agriculture seem like natural additions if funding was available.

In the next few years, we probably need to learn how to better market what we know, what we can do. We are doing this in homespun fashion, but this could be done a lot more effectively.

Western Water Assessment

What do we know now that we did not know five years ago?

The vision for the Western Water Assessment (WWA) project is *to work within an evolving social context and increase the relevance and value of scientific information in order to improve decision-making strategies.* In this approach, the research focuses on the decision-making processes of the individuals, groups, and organizations in the Interior West that have responsibility for managing water resources, as well as those who use the water, and those responsible for its treatment and the protection of the aquatic environment. By understanding the decision making processes, the stresses, and the constraints of this diverse community, researchers can develop hydro-climate products that meet a suite of user needs, allowing the user community to make the best possible decisions.

A number of important research findings are emerging from this endeavor. One example addresses the problem of scarcity of water resources under conditions of sustained regional population growth and climate variability. Leaders of the Colorado water management community are concerned about their ability to satisfy the new and competing demands for water, particularly in light of increased difficulties in obtaining water from neighboring basins, constraints imposed by interstate obligations, the increasing value placed on environmental protection, and the impacts of regional growth on water quality. These concerns are exacerbated by climate variability. For example, in-stream water rights for environmental protection are comparatively junior, and cannot be relied upon to maintain water levels during times of drought. Many regions in the West are currently experiencing drought, and some cities in the Denver-metro area (e.g., Aurora) are concerned about the adequacy of supplies for meeting demands in the summer of 2002. This research emphasizes the unquestionable necessity to properly plan for the combined impacts of regional growth and climate variability in a basin-wide framework that appropriately balances the competing demands for water. In response, WWA scientists are currently developing a comprehensive model-based methodology for regional planning. The intent is to understand the benefits and pitfalls (and third-party effects) of various strategies that may be used to cope with water shortages under different climate regimes, and identify innovative management practices that will both sustain economic prosperity and protect the environment.

Another highlight is the WWA research on the potential use of climate information to improve annual reservoir operating plans. Reservoir managers in the Interior West are currently faced with the challenge of providing water for new uses (e.g., in-stream flows, recreation), while still meeting the needs of traditional rights holders and uses (e.g., irrigation, hydropower). Better use of climate information is one tool that may enable reservoir managers to meet these new uses while minimizing conflicts. WWA researchers have focused on specific problems of current concern to reservoir managers (e.g., the increasing need for environmental protection), and organized climate information needs in terms of an annual calendar of decisions. This decision calendar delineates the times of the year that specific types of climate information are most relevant and most useful. The decision calendar has provided a springboard that has encouraged WWA scientists to develop partnerships with reservoir managers to improve the quality, relevance, use, and value of climate information. These partnerships are resulting in improved methods for climate monitoring, development of procedures to use seasonal climate outlooks in reservoir operating plans, and improved short-term streamflow forecasts to optimize the management of water and increase in-stream flows for environmental protection. More uses of climate information are emerging, leading to both higher efficiencies and improvements in environmental protection.

What are the major climate-related policy issues facing the region over the next five years?

Future climate-related policy issues in the Interior West are many and varied. While water supply availability for municipal, agricultural and industrial uses is likely to remain the primary concern in most locales, several related concerns exist pertaining to the relationship of water resources to environmental protection, fire management, energy production (and demand), recreation and tourism, and, more generally, public lands management. This suite of issues is growing in breadth, complexity, and urgency for a variety of reasons, including the stress on resources associated with rapid population growth and urbanization in the West.

In order to better link scientific understanding of climate variability to the water-related laws, policies and decision processes of the West, a long list of institutional issues demand greater attention. This is a core message of a recent National Research Council study entitled

Envisioning the Agenda for Water Resources Research in the Twenty-First Century (2001) which describes water institutions research as "particularly urgent" (page 33), with research and reforms needed to "emphasize flexibility and facilitate the management of water scarcity" (page 35). In most cases, these institutional issues are not new, nor are they expected to soon vanish from the public policy agenda. These are long-term concerns, and despite local nuances, are issues found in relatively similar form across the entire West. A general inventory of water policy issues with particularly strong linkages to (and implications for) western climate variability includes:

- Exploring legal, political, and other institutional obstacles that discourage the conjunctive use of surface water and groundwater as a means of moderating water supply variability;
- Accommodating and protecting public values in water resources - including environmental considerations - in the face of growing demands, privately controlled water transactions, and climatic variability;
- Reconciling federal laws and programs for environmental protection and public lands management with the varied authorized purposes of federal water projects, and with state water laws and programs primarily designed to promote development and guide allocation;
- Exploring regulatory and economic tools for drought response, mitigation, and avoidance;
- Addressing water management challenges associated with the trans-boundary nature of water resources, including the lack of congruence between political regions and hydrologic regions, and the more general problem of fragmented institutions for resources management and decision-making;
- Enhancing the ability of decision-makers and decision-making forums to establish programs and policies in the face of scientific uncertainty, and given the political, legal and logistical impediments to adaptive management approaches; and,
- Evaluate the use of economic incentives, price signals, and market mechanisms to manage water demands, to manage risk, and to promote greater flexibility and reliability in water management.

Climate Assessment for the Southwest Project (CLIMAS)

What do we know now that we did not know five years ago as a result of CLIMAS work?

- ♦ We have developed an initial methodological approach to doing “usable science”, integrating social and natural science while including stakeholders in user-driven basic and applied research. These new approaches have led to the accomplishments listed below.

- ♦ We have documented the processes central to the interaction between stakeholders and producers of climate-related information, and how such interaction shapes decision-making on both sides

- ♦ Our assessments indicate that human vulnerability (and perceptions of vulnerability) to climate is unevenly distributed within and among community livelihood structures in Arizona; it is unlikely that most community members will make extensive use of climate services directly; rather the information will be transmitted through existing institutional/organizational structures such as the Cooperative Extension and stakeholder organizations.

- ♦ We now know the types of regional and site-specific climate information that are helpful in the decision-making process of multiple stake-holder groups: surface water users/managers, farmers, ranchers, forest and fire managers, public health officials; in the SW, the most common need is seasonal rainfall information, forecast months in advance. However, we have documented a wide diversity of detailed climate information needs that go well beyond this most general information requirement.

- ♦ We have identified some of the institutional constraints to use of climate information, how climate knowledge is used, and why some stakeholders do NOT use climate forecasts.

- ♦ We have determined that there is significant SW stakeholder interest in seasonal climate forecasts for locations outside the Southwest; this interest is tied to efforts to establish and maintain competitive advantage.

- ♦ We have determined skill levels associated with a range of experimental and operational winter and summer-time rainfall (and streamflow) forecasts and outlooks; in general, winter-time rainfall can be predicted in the SW region with significantly better skill than summer, although in some situations (e.g., weak El NiÒo or La NiÒa), forecast skill in winter goes down significantly. The most useful new knowledge is that tailored information on forecast skill, previously unavailable, is useful for multiple types of stakeholders.

- ♦ We now have improved diagnostic and predictive information for the understanding and forecasting of North American monsoon (summer rainfall) variability, especially for the SW region. In particular, we have identified the variable synoptic controls on intraseasonal SW regional precipitation variability and coupling/decoupling to Great Plains precipitation variability. Moreover, we have identified key non-ENSO SST regions in the Pacific and Atlantic that add forecast skill 1-6 months in advance. Our experimental monsoon forecast outperformed other experimental and operational forecasts in the first year of its application.

- ♦ We have determined that most national and international climate forecasts/outlooks are presented in ways (e.g., on the www or hardcopy) that are confusing and misinterpreted by stakeholders. As a result of dialogs with stakeholders, we have determined ways to make climate forecast/outlook information more useful. We have also determined how to “downscale” climate information in ways that enhance usability by stakeholders, and have begun to understand controls on the sub-regional precipitation that is so important to stakeholders. Continental-scale forecast/outlook products produced by existing experimental and operational programs are not optimal for users.

- ♦ We documented for the first time the links between climate variability, land-use and valley fever disease (valley fever is the leading serious (i.e., sometimes fatal) infectious disease of the region. Established that climate can influence valley fever over a 2-4 year period, via monthly variation in temperature, precipitation and soil moisture conditions. Developed an experimental predictive model of valley fever incidence.

- ♦ Special focus on Sulphur Springs Valley (SSV) case study of groundwater dependent agriculture in the SW:
  - ✓ Access to water is the principal limiting factor for farm owners in the region. Its availability is largely determined by depth to which water has to be pumped and the costs of pumping that water. Climatic conditions and events (i.e. temperature, cloud cover, solar radiation, and wind) influence the water needs of plants and determine to a large extent the availability of water, evapotranspiration rates, and soil moisture

levels. Technological adaptations across sectors have focused on increasing the efficiency of water extraction and use.

- ✓ High water costs place SSV farmers at an economic disadvantage vis-a-vis farmers in other parts of the U.S. and the world. To reduce this vulnerability farmers in the SSV look for climate forecasting information in competing regions within the US and around the world.
- ✓ Unexpected and short-term extreme climatic events are a common concern to all stakeholders. On the one hand, frost, heavy rain, strong winds, hail, and floods can be more damaging that a season-long drought. On the other hand, farmers expect and have adapted to a great deal of climatic variability from one year or season to the next. While there is profound interest in better forecasts of an unusual event, concern about changes in annual average conditions is relatively low. Thus, forecasting information that ties climate to specific events is most useful.
- ✓ There is a general distrust of climate and weather information in relation to Monsoon rains. As explained by a farmer: "we can watch all the reports we want. We might get a lot of rain here and our neighbor might not get a drop."
- ✓ Farmers tend to combine information from forecasts with their own experience; those who have been in the region for a long time and come from farming families are at an advantage.
- ✓ Farmers expressed the need for climate information more finely tuned to the local area, including historical data. They emphasize that the SSV falls in between the locations typically given on the prediction models (Tucson and El Paso). They also emphasize that the valley's 4,000-foot elevation results in significant differences in temperature from Tucson.
- ✓ There is interest in the longer-term changes in climate that would affect the water table and irrigation. Since farmers perceive that winter precipitation is the main source of aquifer recharge, they want winter precipitation forecasts that extend into the future (two to five years).
- ✓ Farmers would like a list of available climate information web-sites that is easily accessible. In the words of one farmer: "In the NOAA web-site you have to stumble around for a couple days to find what you really need. It would be nice if NOAA had a link on their home page for agricultural predictions".
- ✓ Farmers concerns about climate are influenced by their perceptions of their own adaptive capacity. In most cases, they perceive that the vulnerability of agriculture has declined because of available technology and larger societal-scale adaptations such as crop insurance.
- ✓ Farmers rely on both vertical (institutional), and horizontal (social capital) networks to reduce vulnerability to climate variability. These formal and informal networks provide access to climate information and to financial and other assets that allow farmers to respond to climate and adapt.

What are the major policy issues facing each region over the next five years that have been identified as priority for stakeholders?

- ♦ We will need a thorough understanding of the opportunities and constraints to policy implementation and change in view of the need to respond and adapt to climate variability/change. For that we need to understand stakeholders' (policy makers) decision-making processes, especially considering the array of formal institutional arrangements existing at the federal, state, and binational level (in relation to the U.S.-Mexican border).

- ♦ We need to understand the interactions between climate variability and climate change, with particular reference to predictability and the potential for surprise climate behavior that has large negative impacts on stakeholders of the region. Ensuring the sustainability of SW economic growth in the face of climate change needs to be a focus of RISA research.

- ♦ We need a stronger education and public outreach infrastructure to help various stakeholder groups understand and plan with climate variability in mind; this has to be done in a "multi-stress" decision-support framework that includes not just climate, but other issues as well.

- ♦ Similarly, we need to do more with regard to studying and targeting information to "middlemen" and""boundary organizations." How, when, where and why does climate and other environmental information enter the decision-making process? This will vary significantly among stakeholder groups' both commonalties and differences need to be identified and tapped.

- ♦ The roles of the private versus public sectors in climate research, assessment and services need to be addressed. Each sector has its roles, and each is needed to serve the stakeholders in a cost-effective manner.

- ♦ We need continued work on nature and causes of summer monsoon variability with a goal of improved forecast skill (we work with the North American Monsoon Experiment science program, as well as on applied stakeholder-oriented aspects in our region). Similarly, the skill of non-summer rainfall forecasting also needs substantial improvement in order to meet the needs of stakeholders.

- ♦ We need to address the wider range of stakeholder climate needs beyond precipitation. For example, numerous stakeholders need better forecasts of wind, relative humidity, frost, extreme events (droughts, floods), and lightening.

- ♦ We must improve understanding and predictability of sub-regional climate variability and impacts for the SW.

- ♦ Significant research and improvements are needed in the area of climate information product style, content, format, and visualization; this work will likely lead to steady increase in climate information use by stakeholders.

- ➢ *Agriculture and Ranching*. Much remains to be done as described in general above, but in particular, we need to improve our understanding of the physical impact of ENSO phenomena on agricultural livelihoods. Moreover, it will be important to assess the ways in which ENSO signals are portrayed in the media and the corresponding effects on farm-level decision-making. A new issue will be assessing the impact of the New Farm Bill on the ability of farmers to adapt to climate variability and change.

- ➢ *Public Health*. We need to improve valley fever predictive skill, and also investigate other emerging climate-health issues, particularly in the face of continued rapid population increases. Focused research, forecast development, and mitigation programs are needed for dengue, encephalitis, influenza, Hantavirus and possibly other infectious diseases that threaten humans in the SW region.

- ➢ *Public Health.* Focused efforts are needed to understand the linkages between climate variability and air quality planning, particularly with regard to SW regional urban smog, desert dust and wildfire issues.

- ➢ *Water*. Greater focus on water management in an era of Colorado and Rio Grande Basin contests; prospects of stronger regulation in certain areas where growth may be outstripping water supply. More specifically, need to 1) develop management strategies appropriate for agriculture, municipal and industrial water-using sectors in response to changes in water supply variability; 2) identify cost effective public policies to protect water dependent fish and wildlife and water quality under conditions of increased water supply variability; and 3) develop policy tools to respond to drought and water supply uncertainty, facilitate resilient and flexible water use across water using sectors and encourage appropriate investments in water conservation and infrastructure improvements.

- ➢ *Water and Agriculture*. Urban water users can manage their vulnerability to climate variability in part by purchasing agricultural water or water rights. However, any reduction in agriculture will have other impacts on rural communities. These issues must be assessed in a multi-stress context that includes climate variability and change.

- ➢ *Border Issues*. Need to develop and use knowledge on climate variability linkages with international migration, transboundary water and air quality management.

- ➢ *Wildland Fire*. An increased focus on urban-wildland interface expansion, biodiversity impacts and air quality issues will be required.

- ➢ *Conservation/biodiversity*. Many stakeholder decisions increasingly must incorporate consideration of conservation and biodiversity concerns, and these issues thus constitute critical stresses that must be considered in concert with climate in the decision-making process. Research in this area is needed, particularly given the rapid ongoing economic and population growth in the SW region.

- ➢ *Mining*. Climate-related impacts on large active and historic mineral mining operations will be increasingly critical for effective pollution mitigation.

- *Energy*. Climate-related pressures on energy availability and costs must be assessed, particularly in the face of continued rapid climate change (regional warming) and population growth.

- *Rural Livelihoods*. Tourism and climate interactions exist and need to be assessed, along with climate forecasting in the context of irrigated agriculture and ranching.

- *Urban Areas*. Urban growth in the region is the fastest in the nation, and research/assessment efforts must be made to aid in the coping of multiple environmental stressors (e.g., climate, air quality, water, infectious disease, biodiversity) in managing large, sprawled urban areas.

How are projects designed to meet stakeholder interest in your region?

CLIMAS was designed to meet stakeholders interests (and needs) in two innovative ways. First, CLIMAS has explicit social science research strategies to assess what stakeholder interests/needs are, and how best to meet them. When information products are developed, CLIMAS then assesses the success of the products and how to make improvements. Second, CLIMAS is not just a partnership between social and natural scientists, it is also a partnership between scientists (and students) and the stakeholders themselves. We are in regular communication with the stakeholders to carry out our assessments of needs and ability to meet these needs. We also make every effort to listen, and to be responsive to what we hear. This approach is different, particularly given the fact that we avoid the "love 'um and leave 'um" approach the stakeholders are used to when dealing with researchers or agency people - our goal is to sustain partnerships, and to always be learning from them (this goes both ways - all partners learn). The need to sustain partnerships, and in particular be responsive to partner (stakeholder) needs creates larger demand on resources - both for "service and information" activities, but also for accelerated knowledge creation (e.g., for improvements in climate prediction and multi-stress integrated knowledge).

How is money used and, in particular, leveraged?

Our NOAA RISA funds are greatly leveraged in many ways. First, the stakeholder (user) driven nature of CLIMAS work leverages much of the other environmental science going on at the university (and broader scientific community). Our goal is to tap basic science for use by stakeholders. Thus, projects funded by NASA, NSF, EPA and other agencies are heavily leveraged. In this way we provide stakeholders with increasingly integrated knowledge and agency "payoff." Moreover, we leverage against the wealth of university programs that also are funded by state, private and other sources. A great deal of student and faculty time is leveraged by the other sources of funding that underwrite this participation. When it comes to working with stakeholders, we find substantial leverage in working with operational entities that are charged with working with stakeholders - Cooperative Extension, National Weather Service, Forest Service, etc. Working with these entities also help us build and sustain partnerships with stakeholders.

What resources will we need to do the job?

To meet the growing and anticipated stakeholder demand, we estimate that a total of $7.5M of new funding will be required for the SW region as detailed below. This would be on top of increased national infrastructure in the areas of climate observations, modeling and process study research.

SW Climate Science and Assessment. The critical mass for SW regional user-driven (stake-holder-driven) climate science and assessment is about $2.5M/yr for the heavily intertwined research and assessment. Of this total, we anticipate that ca. $2M is needed for the core University of Arizona activities, along with ca. $0.5 to fund partners at other universities and federal labs. CLIMAS has already has NOAA-funded (awards pending) links with Scripps, Desert Research Institute (Reno), Climate Diagnostics Center and The University of New Mexico.

Experimental Regional Climate Services. An estimated $0.5M/yr are required at the University of Arizona to develop an experimental regional climate services capability for routine and sustained interaction with stakeholder groups, for developing prototype information products, and for training operational climate services staff (e.g., NOAA NWS). No funds are yet available for experimental or operational stakeholder services, so this responsibility now falls 100% with CLIMAS research/assessment. We are successfully transitioning our wildland fire-climate outlook activity to the National Interagency Fire Center, and are seeking for NOAA funding (the first installment of the above-mentioned $0.5M for stakeholder services) for a climate-oriented UA Extension Specialist to integrate climate knowledge and information into services provided to farming and ranching stakeholders. However, demand for experimental products and services is rapidly outstripping our ability to meet this demand.

Basic Regional Climate Science. In addition to all of the above climate assessment and services resources, increasing stakeholder demand will require greater funding for both the traditional "global" climate science (observing systems, modeling and process studies), as well as more focus on regional scale climate dynamics and predictability. For example, the North American Monsoon Experiment (NAME) is focused on understanding summertime climate variability in the SW and is thus critical for our stakeholders. Also, more effort is needed in the area of high-resolution "regional" climate modeling focused on the topographical complex SW region. The funding needed for regional initiatives like NAME and regional modeling will have to be made available to the national and international climate dynamics research community in order to accelerate the process of making climate science useful. We estimate that this SW-region-specific basic climate research will require an additional $7.5M/year.

The Southeast Assessment

The Florida Consortium of Universities (FLC), consisting of the University of Miami, University of Florida, and The Florida State University, was created in 1996. The purpose of the consortium is to combine resources and expertise of the three Universities to work on the application of climate information (including seasonal-to-annual climate forecasts) to support decision-making in agriculture in the southeastern United States. Our objective is to bridge the knowledge and methodology gap that exists between those who supply climate information and those who make decisions related to agricultural production or other climate-sensitive sectors.

Florida is the nation's ninth ranked agricultural state, with sales of $6.7 billion in 1998. Agriculture had a $20 billion direct impact on the state economy. Florida leads the nation in citrus production, ranks second in vegetables and horticulture production, and fourth in overall crop production. The magnitude and variety of agricultural production in Florida raise questions of which commodities and regions are most influenced by climate. Also, the diversity of Florida's agriculture will place strong demands on a climate information system.

What do we know now that we did not know five years ago?

The Southeast U.S. experiences particularly strong climate shifts, with Florida feeling the greatest impacts. El NiÒo typically brings 30% - 40% more rainfall and cooler temperatures to Florida in the winter, while La NiÒa brings a warmer and much drier than normal winter. Other oscillations and indices affect the climate of North America on decadal and multidecadal time scales (PHO, NAO, AMO), but their impacts apparently are overwhelmed in Florida by the interannual variability of ENSO.

ENSO impacts many aspects of Florida's climate other than average temperature and precipitation. Studies at Florida State University have shown that:

(a) El NiÒo (La NiÒa) greatly decreases (increases) the number of hurricanes that make landfall in the U.S.;

(b) tornado activity is greater in the Deep South during La NiÒa episodes;

(c) damaging freezes in Florida are up to three times more likely during neutral ENSO conditions; and

(d) wildfire activity in Florida is dramatically increased in the spring of La NiÒa episodes.

As far as agricultural impacts are concerned, we analyzed the influence of INSO phases on historical yields of annual field crops (maize, soybean, peanut), sugarcane, vegetables (potatoes, eggplant, strawberry, celery, pepper, tomatoes, snap bean and sweet corm) and citrus (oranges, limes, grapefruit, temples, tangelos and tangerines). We found that several of Florida's high-valued crops are influenced by ENSO:

- During El NiÒo events, winter yields decreased for tomato (77% of long-term average in neutral years), bell pepper (77%), sweet corn (83%) and snap beans (83%) yields;

- Prices increased for bell pepper (31% of average) and snap bean (31%) during El NiÒo episodes;

- In the harvest following El NiÒo events, yields of grapefruit increased (109%) and tangerines (116%) but lime yields decreased (86%);

- Following La NiÒa events, sugarcane yields increased slightly (107%).

As far as wildfire is concerned, the impacts of ENSO in Florida are dramatic. The burn damage across the state during La NiÒa events averages over 200,000 acres per year, more than twice the average annual amount. While the ENSO signal is quite robust in the historical burn data, the limited number of warm and cold events and human intervention such as controlled burns, land use changes, and effective suppression can bias the results. For this reason, a surrogate variable, the Keetch-Byram Drought Index (KBDI), KBDI was chosen for use in an experimental forecast of fire risk. Beginning in 2001, we have prepared a monthly forecast of the KBDI on a county by county level for the entire Florida wildfire season.

There is also a significant ENSO signal in "impact freezes" in Florida. We have identified a dozen "impact freezes" over the last century. Surprisingly, all but one of these events happened during the neutral ENSO phase. This discovery motivated the FC to explore the impacts of ENSO on the occurrence of freezes in Florida. In parts of Northeast, Central, and South Florida, damaging freeze events are up to three times more likely to occur in Neutral years than during El NiÒo or La NiÒa events, with La NiÒa being the least likely. Based on results and the forecast for neutral ENSO phase during the winter of 2001/2002, the FC issued a warning of the increased freeze risk to agriculture, which was broadly disseminated.

Our research results relate not only to how nature works, in the form of the underlying regional climate dynamics and the impacts they produce on Florida's agricultural investments, but they include as well what we have learned about the most effective ways in which scientists can and should communicate with farmers and other agricultural stakeholders. The team, for instance, engaged in a series of rapid surveys to learn from extension agents, farmers and ranchers about agricultural productions systems in Florida, about decisions made by producers that could potentially benefit from climate information, and whether and how climate information is currently being used.

Several general lessons were derived from the various modes of interaction with Florida agricultural stakeholders. Some of these lessons are:

- The very diverse nature of agricultural production in Florida (ranging from row crops to citrus, vegetables, tropical fruits, and ornamentals) will place very strong demands on a climate information system.

- Interest in climate forecasts varied widely among Florida farmers, ranging from no confidence to a high level of optimism.

- Farmers are well aware that weather and climate variability are important in all agricultural production systems. Weather and climate invariably appear on farmers' list of concerns, but *climate is never at the top of the list* in any commodity.

- Farmers producing different commodities generally raise the same issues and indicate a need for similar information before they would use climate forecasts.

- There seems to be varying flexibility to adjust management in response to climate information among farm sizes and types of production.

- We found only a few cases where farmers had already used climate forecasts in their decisions.

- While growers of rainfed crops were concerned about climate fluctuations, market conditions tended to dominate decisions for high-value crops.

- Many growers were sensitive to price impacts of increasing globalization, and wanted climate forecasts for their competitors' regions (in the U. S. or overseas).

- The agricultural Extension Service is viewed by farmers and trade groups as a highly trusted source of information and technical recommendations.

- A successful and sustainable program for application of climate information must attract the interest of Extension specialists and agents in the field.

- A Statewide Major Program (SMP) is a mechanism that legitimizes participation of Extension personnel in activities such as applications of climate information.

In addition, to understand how climate information/predictions can be used, we developed detailed case studies involving four important commodities in Florida: livestock, tomatoes, and peanuts. Each of these studies originated directly from our interactions with farmers and extension agents in these commodities, and built on information from our earlier assessments of ENSO impacts on agriculture in Florida.

Many lessons learned from the case studies relate to specific commodities, sub-regions, and to the characteristics of grower groups, and are described in the white paper. However, some general lessons have been gleaned that are worthy of mention.

Value of Personal Interaction. Involving the Extension system, growers' groups, and other intermediary organizations in the research design and solicitation of additional support not only establishes the legitimacy of our activities in the eyes of decision-makers (e.g., the Florida Commissioner of Agriculture), but also gives us a realistic outlook of possible activities.

Trust in Provider of Information. The main factor defining trust by the farmers was their previous experience with the information provider. This supports our decision to partner with Extension service. It also implies a careful scoping of potential partners as we expand into water resources.

Balancing Research and Intervention. Research identified possible unintended consequences of introducing climate information for certain groups. For example, some smaller scale farmers were concerned that a climate forecast of upcoming bad conditions might lead to insurance companies canceling coverage ahead of time. This illustrated the need to study who might be the 'winners and losers' under different forecast scenarios prior to widespread dissemination efforts.

Models and Common Sense. We have found it useful both to employ formal modeling that may elicit counter-intuitive results and allow quantification of important variables, and to apply common sense to the problems at hand. Although the modeling framework is very useful for organizing knowledge, other approaches must be pursued, so no relevant body of learning is excluded.

Patience. Much of our work involves education of end users, and of the next generation of researchers, and the results of these efforts are not likely to be immediately evident, and it is often months, or years later when we realize that we have made a change in decision-making among some groups, or in various academic fields and their interface.

What are the major climate-related policy issues facing the region over the next five years?

There is a need to expand our agricultural application effort across the SE USA so that after five years, agricultural extension services in at least seven states in the region are routinely providing climate information for decision-making to their clientele and education programs to inform them of this new technology.

There is also a need to extend our focus to water resources management, to investigate how decision-makers in this sector might respond to climate information. Water resources management is the next logical step for the FLC to transition towards a regional climate service because of its economic importance, the clear influence of climate variability on available water resources and the forecast responses inherent in the annual decision cycles of the sector. As a shared resource, water integrates many of the sub-regions and economic sectors of Florida. The goal of initial activities is to scope the current and potential uses of climate information by the institutions that manage Florida's hydrologic resources.

The future mission and goals of the FLC are strongly grounded on our vision of how a climate information system would serve effectively agriculture and water resource management in the SE USA. A useful regional climate information system should involve an interdisciplinary team of physical and social scientists and extension/education specialists which would engage stakeholders in all aspects of planning, implementation, and assessment of its activities. The makeup of the team would evolve over time from one with a predominant research focus to another with a balanced program of research, education, and information delivery to clients.

The regional climate information system we envision would provide downscaled climate forecasts and other climate information to local areas, using variables relevant to decision-makers in the sectors and region involved. It also would develop new methods for linking diverse types of scientific knowledge (climate, social, economic, and sector-specific) for use by decision-makers, providing information on the potential value and associated risks. The system would provide a sustained education and training program for landowners, water managers, cooperating institutions and policy makers. It would incorporate outreach and operational institutions as partners, such as the Cooperative Agricultural Extension Service and Florida Water Management Districts, to reach end user decision-makers through trusted channels.

How are projects designed to meet stakeholders' interests?

The Florida Cooperative Extension Service is a major statewide institution with offices in each county and responsibilities to provide scientifically-based information for use in agriculture and natural resource management throughout the state. It has both dedicated faculty who are engaged with the citizens of Florida, and mechanisms for delivering relevant information to them. For these reasons, the Extension Service is an important partner of the FLC work.

Florida's agriculture is highly diverse and complex. Many markets, products, and institutions have a potential interest in using climate forecasts. For our work to have an impact, we need to prioritize and focus our research process, to explore mechanisms for creating a sustained interest in, and use of, climate information in the agricultural sector, and to evaluate the impact of our work. The Florida Cooperative Extension Service is an ideal partner of the FLC for achieving these goals. The utility of the extension mechanism to the team is enhanced by the information derived from our rapid surveys and case studies.

Summary and Conclusions

We summarize now the main points of the paper before explicitly answering the three questions posed by the Committee.

1. The RISA Program of NOAA/OGP is an important innovation in the conduct of climate science in the U.S.

2. The new climate impact science has at its core a partnership between climate diagnosticians, impacts researchers, and users or potential users of climate forecasts and other information. As such, it is interdisciplinary, problem-focused, and societally robust.

3. At the same time, climate impact science is but a link in a large chain which is designed to give to the United States an “end-to-end” capability in climate science and its applications. The chain begins with basic climate dynamics research, downscaling of global models to regional and sub-regional spatial scales, understanding the forcing functions and patterns of climate variability at regional scales, understanding and explaining to users/stakeholders the impacts generated by these patterns, which are of interest to them, and making predictions on seasonal/ interannual to decadal time scales. The process feeds back on itself to a large extent.

4. This chain rests on both an observational and modeling/computational infrastructure in which there are presently serious gaps. These issues have not been treated here.

5. While the RISA’s have proved the feasibility and utility of the concept of climate impact science, a full reaping of societal benefits requires a much larger national investment than currently exists and the design and implementation of a National Climate Service with regional arms and legs to exist in parallel with the long-standing National Weather Service.

6. Looking solely at the RISA link in the chain, the program is seriously underfunded at a level of FY ’02 $3.3m for five programs, each of which is highly leveraged. This profile leaves a great deal of important work undone. Adequate funding for the present level of effort would be on the order of FY ’03 $10m. This level would need to grow as new regional teams are crated in the future.

We turn now to the questions posed by the Committee.

1. What kind of climate and weather information are needed by “consumers,” such as regional resource managers, farmers, land-use planners, insurance actuaries, and emergency management agencies?

The climate information needed by stakeholders is comprehensively described for each RISA in relation to the question: “What do we know now that we did not know five years ago?” You might think of the climate forecasts issued by the National Center for Environmental Prediction (NCEP) and the International Research Institute for Climate Prediction (IRI) focusing on temperature, precipitation, ENSO and the like as the suite of wholesale products. To make those predictions useable to stakeholders in specific places is the job of “retailing” the forecast. This entails often downscaling forecasts to specific regions and filling in the details. The details refer to how the climate forcing functions actually operate in specific places, what impacts they typically exert on various kinds of natural systems and economic activities which are sensitive to climate variability, and what levels of risk and uncertainly are embedded in the forecasts.

The crucial questions change by location, ecosystems, human ecology, level of economic development, and specific activity. Consequently, “will winter snowpack and spring streamflow be above or below normal this year?” might be a critical question in the PNW but will have no meaning in Florida where “will it freeze?” is definitely one of the critical questions. In the entire Western region of the United States, in fact, water is the central issue while the importance of wildfire shifts from region to region. Without a doubt, in Florida, the central question is the phasing and frequency of ENSO events.

ENSO is also important in the West but El NiÒo and La NiÒa events generate opposite impacts in the PNW as opposed to California. For the PNW, it is not ENSO that is the most powerful climate driver as it is in Florida, it is in fact both the warm and cool phases of the decadal oscillation, the PDO. And the biggest impacts, like high probability of flooding and increased probability of multiyear droughts, occur when ENSO and the PDO are in phase.

In Arizona, the most demanded information across all stakeholder groups is seasonal rainfall forecast months in advance. In addition, the CLIMAS team has produced a major regional innovation in documenting the links between climate variability, land-use patterns, and valley fever disease, a leading infectious disease of the region. The California team, on the other hand, produced another significant innovation in funding effective temperature indicators other than thermometer readings, e.g., first bloom of lilacs or timing of Spring snowmelt runoff. The point here is that types of relevant information of use to stakeholders are not static. They grow as the research grows.

2. Do federal research programs now produce such information, and, if not, what kinds of changes in the federal research agenda are needed to develop such information?

The only Federal research programs which are centrally focused on and systematically produce such *climate* (as opposed to weather) information are the 5 RISA's, each of which is still an experimental activity. The changes required in the research programs are a greater national investment – initially to an annual level of $10m and growing as the number of regional efforts expand, and expanding the observational and national modeling capabilities of the United States. We would repeat, however, that a full flowering of societal benefits from this investment will require the design and implementation of a National Climate Service to handle routine operations and expand service deliveries to stakeholders in specific regions.

3. How would such an expanded research agenda be coordinated with other global change research activities?

The U.S. Global Change Research Program (USGCRP) encompasses the entire chain we have described, from the basic climate dynamics research, through observational and modeling infrastructure, to local, place-based climate impacts research, and finally to working with stakeholders to understand their needs and to provide high quality climate information that is used in planning and decision-making.

One can find evidence for the statement above in a series of recent U.S. National Academy of Science reports which have been published:

Global Environmental Change: Research Pathways for the Next Decade (1999)
Our Common Journey (1999)
Making Climate Forecasts Matter (1999)
Improving the Effectiveness of U.S. Climate Modeling (2001)

The overarching question on climate variability and change for the next phase of USGCRP has been posed in the following way:

How are the climate elements that are important to human and natural systems, especially temperature, precipitation, clouds, winds, and extreme events, affected by changes in the Earth system that result from natural processes and human activities?

It has been explicitly recognized that global changes do not proceed over the planet necessarily in a uniform way and that regional and sub-regional variability is high. Therefore, it is necessary to mount major investigations at regional space scales to provide integrated assessments of the climate system and its impacts in different locales and to provide real-time decision support to stakeholders of all kinds. In this respect, the RISA program of NOAA/OGP has shown the way. Moreover, RISA's are designed to tap, and provide enhanced value for, the large range of Federally-sponsored global change research which originated in the first Bush Administration in the late 1980's. For a relatively small investment, the whole of our global change effort becomes much more of a payoff for society.